(NASA-CR-153810) SUMMARY OF APOLLO-SATURN SPACE VEHICLE TELEMETRY SYSTEMS AND TELEMETRY SUPPORT FROM STATIONS LOCATED IN THE MILA/CAPE AREA FOR APOLLO (Bellcomm, Inc.) 31 p

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BELLCOMM, INC.

SUBJECT: Summary of Apollo-Saturn Space Vehicle Telemetry Systems and Telemetry Support from Stations Located in the MILA/Cape area for Apollo - Case 320

DATE: February 14, 1967

FROM: A. G. Weygand

ABSTRACT

The numbers and types of RF radiating telemetry systems currently planned to be carried by the Apollo-Saturn space vehicles for Apollo-Saturn missions of the AS-200 and AS-500 series are summarized and their modes of operation are discussed. The telemetry support requirements are discussed for both real-time data and data used in post-mission analyses that are imposed on stations in the MILA/Cape area (the MSFN station located at MILA, the telemetry station of the CIF/KSC, and the Cape Tel IV telemetry station of the AFETR) during the launch phase and the earth orbital phase of Apollo missions. Modifications to the implementation plan given in the Saturn IB PSRD, revision 25 and in the Saturn V PSRD, revision 10 for these stations are analyzed.

It is concluded that, without altering the existing or planned capabilities of the MILA MSFN station (with the possible exception of increasing the capacity of the ground communications links between the MILA MSFN station and the CIF), the MILA MSFN station and the CIF (not used for orbital support) can provide the telemetry support of an Apollo-Saturn space vehicle required from stations in the MILA/Cape area during the launch and earth orbital phases of missions AS-205/8 in the AS-200 series and of AS-506 and subsequent missions in the AS-500 series. For missions AS-504 and up, the MILA MSFN station can provide the required VHF telemetry support of the Apollo-Saturn space vehicle after completion of the launch phase. For missions in the AS-200 series and in AS-500 series prior to AS-504, the CIF can provide the required VHF telemetry support required during earth orbit for the time period until the Saturn launch vehicle becomes inactive at which time the MILA MSFN station can provide the required VHF telemetry support so that the CIF can be turned down. Therefore, the requirements imposed on Cape Tel IV by the Apollo Program can be reduced to those of providing VHF telemetry support of the Apollo-Saturn space vehicle during the launch phase of missions AS-204 and 206 in the AS-200 series and the launch phase of missions AS-501 through AS-505 in the AS-500 series.

SUBJECT: Summary of Apollo-Saturn Space Vehicle Telemetry Systems and Telemetry Support from Stations Located in the MILA/Cape Area for Apollo - Case 320

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MEMORANDUM FOR FILE

## 1.0 Introduction

The need for telemetry support of Apollo-Saturn missions by (1) the MILA station of the Manned Space Flight Network (MSFN), (2) the telemetry station of Central Instrumentation Facility (CIF) of the Kennedy Space Center (KSC), and (3) the Department of Defense (DOD) telemetry stations located in the MILA/Cape area are reviewed in this memorandum. This review was undertaken to analyze and to evaluate the necessity for telemetry support by DOD stations in the MILA/Cape Kennedy area during the Apollo-Saturn missions. The Saturn IB Program Support Requirements Document (Saturn IB PSRD) and the Saturn V Program Support Requirements Document (Saturn V PSRD) were used extensively during this review.

The numbers and types of radio frequency telemetry systems currently planned to be carried by the Apollo-Saturn space vehicles for Apollo-Saturn missions in the AS-200 series and the AS-500 series are summarized and discussed in the following sections 2.0 and 3.0, respectively. The telemetry support requirements on stations in the MILA/Cape area as outlined in the suggested telemetry support implementation plan contained in the PSRD's are summarized and discussed in Section 4.0 and alternatives to this currently suggest implementation plan to satisfy the telemetry support requirements on the MILA/Cape area are discussed in Section 5.0.

## 2.0 Telemetry Systems of the Apollo-Saturn Space Vehicle for Missions in the AS-200 Series

A listing of the numbers and types of RF radiating telemetry systems to be carried by the Apollo-Saturn space-vehicles for missions in the AS-200 series has been abstracted from the Saturn IB Program Support Requirements Document, Revision 25. The listing by mission has been arbitrarily

grouped into two tables, which are attached to this memorandom, according to the major changes in the number of telemetry systems carried by the Uprated Saturn I Launch Vehicle. Table 1 refers to mission AS-204 and Table 2 refers to mission AS-205 and subsequent missions in the AS-200 series.

## 2.1 Telemetry Systems of the Uprated Saturn I Launch Vehicle

Each stage (S-IB and S-IVB) and the Instrument Unit (IU) of the Uprated Saturn I Launch Vehicle will be equipped with separate and independent measuring and data transmission systems to minimize the number of stage interfaces and will, in general, carry three types of telemetry systems (PAM/FM/FM (or FM/FM), SS/FM, and PCM/FM) for efficient transmission of the different types of data. All data, including real-time data, transmitted from each stage and IU is required for post-mission analysis purposes.

The PCM/FM telemetry links transfer data from both analog and digital measurements. The PCM system in each launch vehicle stage and the IU includes, in addition to other assemblies, up to six pulse amplitude modulation (PAM) time division multiplexer assemblies, (2) a scanner-timing assembly, (3) an analog-to-digital converter assembly and (4) a digital multiplexer assembly. The PAM multiplexers are synchronized by the scanner-timing assembly and the outputs of the various PAM multiplexers are combined into a programmed sequence determined by the scanner-timing assembly which is then connected to the analog-to-digital converter assembly. The PCM digital output of the analog-to-digital converter assembly is combined with data originating from digital measurements and with synchronization words in the digital multiplexer assembly to form a NRZ-L* PCM bit stream of 72 kilobits/second which is transmitted over the PCM/FM telemetry link.

Up to three different ways of combining the outputs of the PAM multiplexer assemblies may be programmed into the scanner-timing assembly, any one of which can be selected by command (usually generated in the launch vehicle computer in the IU as a function of mission phase). The advantage and utility of this capability is apparent, for example, when the requirements for the transfer of data on the performance

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*Non-return-to-zero level (NRZ-L) - "One" is represented by one level and "zero" is represented by the other level.

of all subsystems in the S-IVB/IU during S-IVB powered flight are compared with the requirements for the transfer of data on the performance of the same systems during coast of the S-IVB/IU in earth orbit.

Each of the PAM multiplexer assemblies has two parallel outputs, one of which is always available to the scanner-timing assembly of the PCM system. The second output is conditioned for transmission as a PAM waveform used to modulate a 70 kHz voltage-controlled oscillator of an FM/FM telemetry system to provide a PAM/FM/FM telemetry link. For the case of a developmental launch vehicle as used in mission AS-204, this capability is provided in all stages and the IU to give redundant transmission of the data from some of the PAM multiplexers by sending it over both a PAM/FM/FM telemetry link and over the PCM/FM telemetry link. This capability for redundant transmission of critical subsystem performance data is not planned to be utilized in the operational launch vehicles (after AS-204).

After completion of the launch powered flight phase of mission AS-204, the SS/FM telemetry links from the S-IVB stage and the IU will not require support from ground-based stations and will cease to transmit shortly after the end of powered flight when their battery supplies are depleted. All telemetry transmissions from the S-IVB stage and IU will cease approximately 4.5 hours after launch during all Apollo Missions in the AS-200 series upon depletion of the battery supplies in the S-IVB/IU. However, missions of the Apollo Applications Program may extend the duration of in-orbit operation of the S-IVB/IU to approximately 7 hours.

### 2.1.1 Real-Time Data

During the launch phase of the missions, real-time decommutation and processing of the data (72 kilobits/second) transmitted over the PCM/FM telemetry links from each stage (S-IB and S-IVB) and IU are required for mission control. In addition, real-time demodulation and processing of the data transmitted over one of the PAM/FM/FM telemetry links from the S-IVB stage is required for mission control during the launch phase of mission AS-204. For AS-205 and subsequent missions, all data required for mission control will be included in the data transmitted over the PCM/FM telemetry links from each stage and the IU.

For mission AS-204 and subsequent missions, the digital data transmitted over the PCM/FM telemetry link from the IU will include all mission control data required in real-

time from both the S-IVB stage and the IU during coast in earth parking orbit. For missions AS-205 and subsequent missions, the digital data transmitted over the PCM/FM telemetry link from the S-IVB stage will include all mission control data required in real-time from both the S-IVB stage and the IU during coast in earth parking orbit except for the bit stream from the launch vehicle digital computer. Real-time decommutation and processing of the data transmitted over the PCM/FM telemetry link from the IU is required for mission control during coast in earth parking orbit. Real-time handling of the PCM/FM telemetry link from the S-IVB stage is not required during coast in earth parking orbit unless the PCM/FM telemetry link from the IU fails. Real-time decommutation and processing of the data transmitted over the PCM/FM telemetry link from the S-IVB stage would be required for mission control during S-IVB stage engine restart preparation and engine operation. (S-IVB stage engine restart is not a current capability of the S-IVB in the remaining missions in the Uprated Saturn I Launch Vehicle.)

### 2.1.2 Recorded Data

Three tape recorders for recording telemetry data will be carried by the Uprated Saturn I Launch Vehicle for mission AS-204, one each in the S-IB stage, the S-IVB stage and the IU. Although ground station telemetry support is required for playback of the on-board recorders for post-mission analysis purposes, real-time decommutation and processing of this playback data by the ground stations is not required for mission control.

The tape recorder in the S-IB stage will be used to record certain data during the retro-rocket firing sequence at separation of the S-IB and S-IVB stages. The baseband analog spectrum of two of the S-IB stage PAM/FM/FM telemetry links will be sent in parallel to the tape recorder and to the FM telemetry transmitter during the retro-fire maneuver. Playback of the S-IB stage telemetry recordings over the existing on-board telemetry links (used originally for real-time transmission of the data that was recorded) in place of real-time telemetry will automatically begin shortly after separation of the S-IB and S-IVB stages.

The tape recorder in the IU will be used in a similar capacity to record the baseband analog spectrum input to the RF FM transmitter of two of the PAM/FM/FM telemetry links in the IU during the retrofire sequence of the S-IB stage. Playback of the recorded data over the existing IU

telemetry links in place of real-time data will be accomplished at some convenient time shortly after completion of the launch powered flight.

The tape recorder carried by the S-IVB stage (which will also be carried during missions after AS-204) will operate in a dual capacity. During the retrofire maneuver of the S-IB stage, the recorder will be used to record the baseband analog data spectrum input to the FM transmitter of three of the S-IVB stage PAM/FM/FM telemetry links. The data thus recorded will be played back over these same FM transmitters at some time after completion of the launch powered flight. In addition during the earth parking orbital coast, the S-IVB stage recorder will be used to record the five most significant bits of alternate ten bit PCM words of the 72 kilobits/second NRZ-L PCM bit stream which would be transmitted in real-time over the PCM/FM telemetry link of the S-IVB stage. Playback of the recorded PCM data over the existing S-IVB stage PCM/FM telemetry link in place of real-time data will be accomplished on command and will be transmitted at a rate of 144 kilobits/second.

## 2.2 Telemetry Systems of the Command and Service Modules (CSM) for Missions in the AS-200 Series

The CSM will carry one operational VHF PCM/FM telemetry system and the Unified S-Band System (USB) during mission AS-204. The NRZ-L PCM data transmitted over the VHF PCM/FM and USB telemetry links will be identical (selectable data formats of either 51.2 or 1.6 kilobits/second) and will contain all mission control data required from the CSM during the mission. Transmission of the 51.2 kilobits/second data format is highly desirable during all mission phases for mission control, however, transmission of the 1.6 kilobits/second will suffice during some mission phases. Since the USB system will still be undergoing tests and evaluation during this mission, the VHF PCM/FM telemetry link will be the primary PCM link and the USB system will serve as a backup. The transmitter of the USB system carried by the CSM during mission AS-204 may be either frequency modulated or phase modulated by NRZ-L PCM data bi-phase modulated on a 1.024 MHz subcarrier, but the USB system does not have the capability of transmitting a phase modulated carrier and a frequency modulated carrier simultaneously. Real-time decommutation and processing of the NRZ-L PCM bit stream (data formats of 51.2 or 1.6 kilobits/second) transmitted over either the VHF or the USB system (but not both simultaneously) are required for mission control. All data transferred from the CSM to ground based stations is required for post-mission analysis.

The CSM will carry a tape recorder during mission AS-204 which will be used to record PCM data at a rate of 1.6 or 51.2 kilobits/second. Playback of the recorded PCM data will be accomplished over the existing VHF PCM/FM and USB telemetry links at a rate of 51.2 kilobits/second in place of real-time PCM data when commanded by the on-board crew or the MSFN.

During AS-205/8 and subsequent missions, the CSM will carry only the telemetry link in the USB system. This USB system will be capable of transmitting both a frequency modulated and a phase modulated carrier simultaneously. Real-time PCM data (selectable data formats of either 1.6 or 51.2 kilobits/second) will phase modulate a 1.024 MHz subcarrier which will in turn phase modulate one USB transmitter. A second S-band transmitter using frequency modulation will be used to transmit data recorded on-board the CSM when commanded by the crew or the MSFN. Real-time decommutation and processing of the data transmitted over the USB telemetry link used for transfer of real-time data (1.6 or 51.2 kilobits/second depending on mission phase) is required for mission control. All data transfered from the CSM to ground based stations is required for post-mission analysis and some of the data not required for processing and analysis in real-time is required for post-pass analysis. The S-band FM transmitter will not require telemetry support during the launch phase of mission AS-205/8.

The CSM will carry a tape recorder during AS-205/8 and subsequent missions which will be used to record split-phase digital telemetry received by the CSM from the LM at a rate of 1.6 kilobits/second and to record CSM PCM data at a rate of either 1.6 or 51.2 kilobits/second. Playback of the recorded CSM PCM data (always at an apparent rate of 51.2 kilobits/second) will bi-phase modulate a 1.024 MHz subcarrier which will frequency modulate the S-band transmitter. Playback of the recorded LM split-phase PCM data at a tape speed increase of 8 to 1 or 32 to 1 (depending upon tape speed during the recording of the data) will frequency modulate the S-band transmitter. Simultaneous transmission of the playback of the recorded PCM data and the recorded LM split-phase PCM data will not be possible. Transmission of the playback of recorded telemetry will not interfere with transmission of real-time telemetry from the CSM.

## 2.3 Telemetry Systems of the Lunar Modules (LM) Used for Missions in the AS-200 Series

In addition to the VHF PAM/FM/FM and VHF FM/FM (constant bandwidth) telemetry systems, the LM, for missions

AS-206 and AS-205/8, will carry one operational VHF PCM/FM telemetry system and the Unified S-Band System (USB). All of the data required from the LM in real-time for mission control will be digital and incorporated into selectable NRZ-L PCM bit streams of 1.6 or 51.2 kilobits/second (the 51.2 kilobits/second data format is highly desirable during all mission phases but the 1.6 kilobits/second format will suffice during some mission phases) either of which will be transmitted in parallel over the USB and VHF PCM/FM telemetry links. The transmitter of the USB system in the LM may be either frequency modulated or phase modulated (but not both simultaneously) by real-time PCM data bi-phase modulated on a 1.024 MHz subcarrier. Since the USB system will still be undergoing evaluation in these missions, the VHF PCM/FM telemetry link from the LM will be the primary link and the USB telemetry link will serve as a backup. Real time decommutation and processing of the NRZ-L PCM bit stream transmitted over either the VHF or the USB Telemetry (but not both simultaneously) are required for mission control. All data transferred from the LM to ground-based stations is required for post-mission analysis. Support for the VHF telemetry links from the LM during launch is required during mission AS-206 but is not required during mission AS-205/8. Support for all telemetry links from the LM is required during the earth orbital phases of missions AS-205/8 and 206.

In addition, the LM (except during mission AS-206) will carry a VHF transmitter which will be amplitude modulated (AM) by either voice or by split-phase PCM data from the LM at a rate of 1.6 kilobits/second for transmission to the CSM. This link will be used to permit the CM to record LM telemetry data when the LM is behind the moon. This PCM data will be identical to the low bit rate data that will be transmitted over the VHF PCM/FM and the USB telemetry links to the MSFN from the LM. Use of the AM transmitter for telemetry transmission constrains the PCM data transmission rate to 1.6 kilobits/second. The split-phase PCM bit stream is derived from the 1.6 kilobits/second NRZ-L bit stream.

## 3.0 Telemetry Systems of the Apollo-Saturn Space Vehicle for Missions in the AS-500 Series

A listing of the numbers and types of RF radiating telemetry systems currently planned to be carried by the Apollo-Saturn space vehicles for missions in the AS-500 series has been abstracted from the Saturn V Program Support Requirements Document, Revision 10. The listing by mission has been arbitrarily grouped into three tables, which are

attached to this memorandum, according to the major changes in the number of telemetry systems carried by the Saturn V Launch Vehicle. Table 3 refers to missions AS-501, 502, and 503, Table 4 refers to missions AS-504 and 505, and Table 5 refers to mission AS-506 and subsequent missions.

### 3.1 Telemetry Systems of the Saturn V Launch Vehicle

Each stage (S-IC, S-II, and S-IVB) and the Instrument Unit (IU) of the Saturn V Launch Vehicle will be equipped with separate and independent measuring and data transmission systems in order to minimize the number of stage interfaces and will, in general, carry three types of VHF telemetry systems (PAM/FM/FM or FM/FM, SS/FM, and PCM/FM) for efficient transmission of the different types of data. All data transmitted from each stage and IU is required for post-mission analysis purposes.

The PCM/FM telemetry links transfer data originating in both analog and digital form. The PCM system in each stage and IU includes, in addition to other assemblies, up to six PAM multiplexer assemblies, a scanner-timing assembly, an analog-to-digital converter assembly, and a digital multiplexer assembly. The PAM multiplexers are synchronized by the scanner-timing assembly and the outputs of the PAM multiplexers are combined into a programmed sequence determined by the scanner-timing assembly before being fed to the analog-to-digital converter assembly. The PCM output of the analog-to-digital converter assembly is combined with data originating from digital measurements and with synchronization words in the digital multiplexer assembly to form a NRZ-L PCM bit stream of 72 kilobits/second which is transmitted over a PCM telemetry link.

Up to three different ways of combining the outputs of the PAM multiplexers may be programmed into the scanner-timing assembly, any one of which can be selected by external command. Each PAM multiplexer assembly has two parallel outputs, one of which is always connected to the scanner-timing assembly. The second output is conditioned for PAM transmission for possible transmission over PAM/FM/FM telemetry links. During early launch vehicle missions (AS-501 through AS-503 and possibly AS-504 and 505), this capability is used in all stages and the IU to provide redundant transmission of the outputs of some of the PAM multiplexers containing data on the performance of critical subsystems. This capability is not planned to be utilized in operational launch vehicles (after AS-506).

In addition to the large complement of VHF telemetry systems carried by the Saturn V Launch Vehicle, two telemetry links operating at frequencies in the S-band will be carried in the IU; namely, (1) the Command and Communications System (CCS) and (2) a conventional PCM/FM telemetry system. It should be noted that there is a possibility that one of the S-band telemetry links (most likely the PCM/FM link) from the IU may be deleted from operational Saturn V Launch Vehicles. The CCS is a unified system very similar to the USB system carried by the CSM and LM, and has the capability for PCM data transmission.

For missions AS-501, 502, and 503 the PCM data transmitted over the VHF PCM/FM telemetry system from the IU will be transmittted in parallel over both the S-band PCM/FM and the CCS telemetry links. For mission AS-504 and subsequent missions, the VHF PCM/FM and the S-band PCM/FM telemetry systems of the IU will transmit identical NRZ-L PCM bit streams and the VHF PCM/FM telemetry system of the S-IVB stage and the CCS of the IU will transmit identical NRZ-L PCM bit streams. The PCM bit streams transmitted over the various digital telemetry links from the S-IVB stage and IU will include all mission control data required during coast phases of the missions from both the S-IVB stage and the IU including the up-data message acceptance indication. However, during any powered flight maneuvers of the S-IVB stage and during S-IVB engine restart preparations in Earth orbit, there is some data required for mission control which appears in the PCM bit stream transmitted from the IU or in the digital bit stream transmitted from the S-IVB stage but not in both.

### 3.1.1 Real-Time Data

During the powered flight phases of the missions, real-time decommutation and processing of the data (72 kilobits/second) transmitted over the PCM/FM telemetry links from each stage (S-IC, S-II, and S-IVB) and IU are required for mission control. The VHF PCM/FM telemetry links from the S-IVB and IU are the primary PCM telemetry links during launch and real-time handling of S-band PCM telemetry links from the S-IVB and IU is not required unless the corresponding primary link fails. In addition, real-time demodulation and processing of the data transmitted over PAM/FM/FM telemetry links from the S-IC and S-II stages are required for mission control during launch.

During the earth orbital coast phases of Apollo-Saturn missions, the VHF PCM/FM telemetry system of the IU is planned to be the primary PCM telemetry link for transfer of S-IVB/IU mission control data. In case of failure of this link, back-up links, in order of preference, will be the S-band PCM/FM telemetry link from the IU, the VHF PCM/FM telemetry link from the S-IVB stage, and the CCS link from the IU. At some time after completion of the injection maneuver, the S-band PCM/FM telemetry link from the IU will become the primary PCM telemetry link for the transfer of S-IVB/IU mission control data to ground-based stations and the CCS will serve as the back-up to this system. Real-time decommutation and processing of the data transmitted over the primary PCM telemetry link (or over the secondary PCM telemetry link in the event of primary PCM telemetry link failure) from the S-IVB/IU are required for mission control during all coast phases of the missions. Real-time decommutation and processing of the data transmitted over a PCM telemetry link from both the S-IVB stage and the IU is required for mission control during S-IVB stage engine restart preparation and engine operation.

### 3.1.2 Recorded Data

During missions AS-501, 502, and 503, the Saturn V Launch Vehicle will carry five tape recorders for recording telemetry data, one each in the S-IC stage, in the S-IVB stage, and in the IU and two in the S-II stage. Although ground station telemetry support is required for playback of the on-board recorders for post-mission analysis purposes, real-time handling of this playback data by the ground stations is not required.

The tape recorder carried by the S-IC stage will be used to record the baseband analog spectrum input to the FM transmitter of one of the PAM/FM/FM telemetry systems of the S-IC stage during S-IC staging and retrorocket firing sequence. Playback of the recorder over the S-IC stage on-board telemetry system associated with the link that was recorded in place of real-time data will begin automatically shortly after S-IC stage separation.

The two tape recorders (two channels on each) carried by the S-II stage will be used to record the analog baseband spectrum inputs to the FM transmitter of each of the three PAM/FM/FM telemetry systems of the S-II stage and to record the analog output of one of the PAM multiplexers located in the S-II stage during both the staging and retro-firing sequence of the S-IC stage and during staging and retro-firing sequence of the S-II stage. Playback of the S-II stage recorders over four existing

S-II stage on-board telemetry systems (the FM transmitters from the three PAM/FM/FM telemetry links and from one of the SS/FM telemetry links) will be accomplished after S-II stage separation from the S-IVB stage.

The tape recorder carried by the IU will be used to record the analog baseband spectrum input to the FM transmitter of two of the PAM/FM/FM telemetry systems of the IU during retro-rocket firings and at other prescribed times. Playback of the recorder will be accomplished over existing IU on-board telemetry systems, with the playback output baseband from the recorder used to modulate the VHF FM telemetry transmitter in the IU associated with the link that was recorded in place of real-time data.

The tape recorder carried by the S-IVB stage will be used to record the analog baseband spectrum input to the FM transmitter of each of the three PAM/FM/FM telemetry systems of the S-IVB stage during staging and will playback the recorded data using the respective VHF telemetry transmitters associated with the links that were recorded upon command by the LVDC or the MSFN at some convenient time after completion of launch powered flight. This same recorder will be used to record digital data during earth orbital coast, recording the five most significant bits of alternate 10 bit words in the 72 kilobit/second NRZ-L PCM bit stream which is transmitted in real-time over the VHF PCM/FM telemetry system of the S-IVB stage. Upon command by the launch vehicle computer or the MSFN, the recorded PCM data will be played back at a rate of 144 kilobits/second and modulate the transmitter of the S-IVB PCM/FM telemetry system, in place of the real-time PCM bit stream.

## 3.2 Telemetry Systems of the Command and Service Modules Used for Missions in the AS-500 Series

During missions AS-501 and 502, the CSM will carry (1) an operational VHF PCM/FM telemetry system, (2) the USB system for backup and verification and (3) a tape recorder. These systems will be operated in the same manner as described for mission AS-204 in Section 2.2 of this memorandum.

During mission AS-503 and subsequent missions, the CSM will carry the USB system and a tape recorder which will be operated in the same manner as described for mission AS-205/8 in Section 2.2 of this memorandum.

## 3.3 Telemetry Systems of the Lunar Modules Used for Missions in the AS-500 Series

The LM flight test articles (LTA) used in missions AS-501 and 502 will carry VHF PAM/FM/FM and FM/FM (constant bandwidth) telemetry systems. Although these systems require support from the ground stations throughout the mission for post-mission analysis purposes, none of the data transmitted over these telemetry links is necessary for real-time mission control.

The LM used in mission AS-503 will be instrumented and operated in the same manner as the LM used in mission AS-205/8 which is discussed in Section 2.3. It should be noted that there is a possibility that this LM will not be equipped with telemetry portion of the Development Flight Instrumentation (DFI). If this should be the case, this LM will be instrumented and operated in the same manner as the LM used in mission AS-504 described below.

The LM used in mission AS-504 and subsequent missions will carry the USB system to provide telemetry transmission to the ground stations and a VHF AM transmitter to provide telemetry transmission (or voice transmission) to the CSM. All of the data required from the LM in real-time for mission control will be digitized and incorporated into NRZ-L PCM bit streams of 1.6 or 51.2 kilobits/second (the data format used will depend on mission phase). The transmitter of the USB may be either frequency modulated or phase modulated (but not both simultaneously) by a 1.024 MHz subcarrier which has been bi-phase modulated with real-time NRZ-L PCM bit streams. Real-time decommutation and processing of the LM data transmitted over the USB telemetry link are required for mission control during the phases of the missions when it is active but not during the launch phase of the missions.

When PCM data is being transmitted over the USB telemetry link at the lower rate of 1.6 kilobits/second or when the USB telemetry link is not being used (as behind the moon), a VHF AM transmitter may be amplitude modulated by split-phase PCM data at a rate of 1.6 kilobits/second. The split-phase PCM bit stream is derived from the 1.6 kilobit/second NRZ-L PCM bit stream that would have been transmitted over the USB telemetry link.

# 4.0 Telemetry Support Requirements

## 4.1 General

The following overall program telemetry coverage and support requirements form the basis of the specific telemetry

support requirements levied on the stations located in the MILA/Cape area by the PSRDs:

(a) Reception and recording of all telemetry transmissions from the Apollo-Saturn space vehicle whenever the ground-based telemetry support sites have acquired the space vehicle.

(b) Pre-detection recording of the PCM/FM and SS/FM telemetry transmissions from the space vehicle is highly desirable; any additional existing capacity of the pre-detection recording systems should be utilized to record the FM/FM and PAM/FM/FM telemetry transmissions.

(c) Recording of the received telemetry signal strength whenever the ground-based telemetry support sites have acquired the space vehicle.

(d) Continuous reception recording of all telemetry transmissions from the space vehicle launch powered flight phase of the mission.

(e) Reception and recording of all telemetry transmissions from the space vehicle by at least two stations simultaneously is highly desirable during the launch powered flight phase of the mission.

(f) Polarization diversity reception of VHF telemetry transmissions from the space vehicle (receive with both right and left circular polarization and combine the signals) whenever possible during powered flight phases of the mission.

(g) Continuous real-time decommutation of selected telemetry transmissions from the space vehicle and transmission of the flight control data to the Mission Control Center in Houston (MCC-H) and/or display at the ground-based station to provide the capability for continuous monitoring of the crew and selected space vehicle system parameters in real-time to permit mission control during the launch powered flight phase of the mission.

(h) Reception and recording of telemetry transmissions from the spent stages of the Saturn launch vehicle during ballistic flight following separation during the launch phase is highly desirable.

(i) Real-time decommutation of selected telemetry transmissions from the space vehicle and transmission of flight control data to MCC-H and/or display of the flight control data at the ground-based station to permit evaluation in real-time or as soon after significant events as possible to facilitate mission control during the earth parking orbital phases of the mission.

(j) Necessary telemetry reception and PCM decommutation capability at all ground-based stations provided with an up-data transmission capability in order to obtain up-data validation information for the up-data system.

(k) Reception and recording of transmissions from the space vehicle of the playback of data recorded onboard the space vehicle.

## 4.2 Current Requirements on Stations Located in the MILA/Cape Area for Telemetry Support of Apollo-Saturn Missions

The Saturn IB and the Saturn V Program Support Requirements Documents request the use of the Central Instrumentation Facility (CIF) of the Kennedy Space Center (KSC), the Cape Tel IV station of the Air Force Eastern Test Range (AFETR) and the MILA station of the Manned Space Flight Network (MSFN) to fullfill the MILA/Cape area telemetry support requirements. However, it is stated in the PSRDs that the allocation of the available telemetry support stations as requested in the documents is not rigid providing that the basic support requirements are met. The telemetry support requested in the PSRDs for the Apollo-Saturn missions from the three above mentioned stations are summarized below.

### 4.2.1 Launch Powered Flight

During the launch powered flight phases of the mission:

(a) Continuous reception and recording of all VHF PAM/FM/FM, FM/FM, SS/FM, and PCM/FM telemetry links from the Apollo-Saturn space vehicle by both the CIF and the Cape Tel IV stations.

(b) Polarization diversity reception (hence twice the number of receivers are required) and signal combination for all VHF telemetry links from the space vehicle by both the CIF and the Cape Tel IV stations.

(c) A secondary antenna system of both the CIF and the Cape Tel IV stations to follow the S-IB stage (or S-IC stage) after S-IB/S-IVB stage separation (or S-IC/S-II stage separation) to permit reception and recording of post separation data from the spent stage(s) while the primary antenna systems of these stations continue to follow the live upper stages of the space vehicle.

(d) Continuous decommutation and processing of the data transmitted over selected VHF telemetry links (both PCM/FM and PAM/FM/FM links) from the space vehicle by the CIF station for insertion into the Data-Core of the Apollo Launch Data System (ALDS) for transmission to the MCC-H to permit real-time mission control.

(e) Real-time remoting of selected VHF PCM/FM, FM/FM and PAM/FM/FM telemetry links by the Cape Tel IV station to the CIF for decommutation and processing prior to insertion into the Data-Core of the ALDS.

(f) Continuous reception and recording of all S-band telemetry links from the Apollo-Saturn space vehicle by the MILA MSFN station.

(g) Continuous real-time decommutation and processing of the data transmitted over selected USB telemetry links from the spacecraft and the Instrument Unit by the MILA MSFN station for real-time transmission to the MCC-H via the Data-Core of the ALDS and/or a high speed data (HSD) line.

4.2.2 Coast in Earth Parking Orbit

Whenever the respective station in the MILA/Cape area is in line-of-sight of the space vehicle during the earth parking orbital phases of the mission, the requirements are as follows:

(a) No requirement for the CIF or the ALDS to be active (except perhaps during missions AS-501 and 502).

(b) Reception and recording of all VHF telemetry links from the space vehicle by the Cape Tel IV station.

(c) Polarization diversity reception and signal combination for all VHF telemetry links from the space vehicle by the Cape Tel IV station.

(d) Real-time remoting of selected VHF PCM/FM telemetry links by the Cape Tel IV station to the MILA MSFN station for decommutation and processing prior to transmission to the MCC-H.

(e) Reception and recording of all S-band telemetry links from the space vehicle by the MILA MSFN station.

(f) Reception and recording of selected VHF telemetry links from the spacecraft by the MILA/MSFN station.

(g) Real-time decommutation and processing of a total of three PCM telemetry links, either VHF or S-band, by the MILA MSFN station for real-time transmission to the MCC-H via a HSD line.

(h) Recording of the AGC voltage of their respective telemetry receivers by the Cape Tel IV and the MILA MSFN stations complete with suitable calibrations to provide a record indicating received RF signal strength for the various space vehicle telemetry links.

## 4.3 Upper Bound of the Requirements on Stations Located in the MILA Cape Area for Telemetry Support of Apollo-Saturn Missions

Examination of Tables 1 through 5 which list the telemetry systems carried by the Apollo-Saturn spacevehicle for various missions of the Apollo Program and examination of the telemetry support requirements on ground-based stations which were presented earlier in Section 4.0 lead to the conclusion that, of all of the Apollo-Saturn missions, missions AS-501 and 502 require the most telemetry support from stations in the MILA/Cape area during the launch phase of the mission and mission AS-503 requires the most telemetry support from stations in the MILA/Cape area during the earth orbital phases of the mission. (Refer to Table 3 for a listing of the telemetry systems carried by the Apollo-Saturn space vehicle for missions AS-501 through AS-503. It should be noted that the LTA requires telemetry support during launch but that the LM does not.)

### 4.3.1 Launch Powered Flight

During the early portions of the launch powered flight phase of the AS-501 and 502 missions, 11 VHF PAM/FM/FM, 2 VHF FM/FM, 6 VHF SS/FM, 5 VHF PCM/FM, 1 S-band PCM/FM, and 2 S-band PCM/PM/PM telemetry links must be received and recorded by stations in the MILA/Cape area. To provide polarization diversity reception of all of the VHF telemetry links from the Apollo-Saturn spacevehicle as required during the launch powered flight, twice the normal number of receivers are required, or in this instance 48 VHF receivers and 24 diversity combiners are required, exclusive of spares. Since VHF telemetry reception by at least two stations in the MILA/Cape area is required during launch, a total of 96 VHF receivers and 48 diversity combiners, exclusive of spares, are required in the various stations in the MILA/Cape area with a total of 48 VHF receivers and 24 diversity combiners of the above required total being located at each one of two stations. In addition, reception of VHF telemetry from spent stages after separation from the live upper stages of the Saturn launch vehicle is required which in turn requires a separate VHF telemetry antenna to follow the spent stage.

Since neither space nor polarization diversity reception of the S-band telemetry links is required, 2 S-band PM receivers and 1 S-band FM receiver, exclusive of spares, are necessary to provide the required S-band telemetry receive and record support.

Four (4) VHF PCM/FM telemetry links (one each from the S-IC, S-II, and S-IVB stages and the Instrument Unit) and 1 S-band PCM/PM/PM telemetry link (or 1 VHF PCM/FM telemetry link) from the CSM are required to be decommutated and processed in real-time for display and/or transmission to the MCC-H via the Data-Core of the ALDS. In addition, the VHF PAM/FM/FM telemetry links from the S-IC and S-II stages of the Saturn launch vehicle are required to be demodulated and the data processed in real-time for display and/or transmission to MCC-H. It should be noted that the S-band PCM/FM and PCM/PM/PM telemetry links from the launch vehicle serve as backup to the VHF PCM/FM telemetry links from the Instrument Unit and decommutation and processing of either one of these links in real-time are only required if the VHF PCM/FM telemetry link from the IU should fail. Real-time decommutation and processing of the data transmitted over the S-band PCM/PM/PM telemetry link from the CSM is required for transmission to the MCC-H via the Data-Core of the ALDS and/or a HSD line.

### 4.3.2 Coast in Earth Parking Orbit

During the early portions of the earth parking orbital phases of the AS-503 mission, 7 VHF PAM/FM/FM, 2 VHF FM/FM, 3 VHF PCM/FM, 1 S-band PCM/FM, 1 S-band PCM/PM/FM, and 2 S-band PCM/PM/PM telemetry links must be simultaneously received and recorded by stations in the MILA/Cape area. Since there is no requirement for space or polarization diversity reception of either the VHF or the S-band telemetry links from the spacevehicle by stations in the MILA/Cape area, a total of 12 VHF telemetry receivers and 2 S-band FM and 2 S-band PM telemetry receivers, exclusive of spares, are required in the various stations located in the area.

Two (2) VHF PCM/FM telemetry links (one each from the LM and Instrument Unit) and 1 S-band PCM/PM/PM telemetry link (from the CSM) are required to be decommutated and processed in real-time for display and/or transmission to the MCC-H via a HSD line.

It should be noted that in the case of either the LM or the S-IVB/IU, data required for flight control by the MCC-H appear on more than one PCM telemetry link, however, real-time handling of only one of the PCM telemetry links from the LM and one from the S-IVB/IU is required at any one time. The LM S-band PCM/PM/PM (or PCM/PM/FM) telemetry link and the IU S-band PCM/PM/PM telemetry link will never be active simultaneously and therefore will not require simultaneous support.

## 5.0 Discussion of the Allocation of Available Capabilities of Stations in the MILA/Cape Area to Meet Telemetry Support Requirements for Apollo-Saturn Missions

The currently suggested implementation plan contained in the PSRDs to meet the overall requirements for telemetry support of the Apollo-Saturn space vehicle by station(s) in the MILA/Cape area for Apollo-Saturn missions as indicated in Section 4.0 is summarized below:

(a) The CIF and Cape Tel IV will provide the required VHF telemetry receive and record support during the launch phase of the missions,

(b) Cape Tel IV will provide the required VHF telemetry receive and record support during the earth orbital phases of the missions,

(c) The MILA MSFN station will provide all required S-band telemetry receive and record support during the launch and earth orbital phases of the missions,

(d) The CIF and the MILA MSFN station will provide the required telemetry link real-time decommutation and data processing support during the launch phase of the missions, and

(e) The MILA MSFN station will provide the required telemetry link real-time decommutation and data processing support during the earth orbital phases of the missions.

Of particular concern in this suggested station implementation to provide the required telemetry support for Apollo-Saturn space vehicles is the economics of the use of the Department of Defense controlled Cape Tel IV station during earth orbital phases of long duration earth orbital Apollo-Saturn missions. Also of economic concern, although not as immediate in nature, is the objective of the Department of Defense to vacate the 225 to 260 MHz (VHF) frequency band for telemetry transmissions from spacecraft and aircraft by 1970. Consequently, NASA would be economically responsible for the VHF portion of the Cape Tel IV station, including the full-time maintenance of the VHF telemetry equipment, if this VHF equipment were required after 1970 for support of Apollo-Saturn spacevehicles. This cost would be in addition to the cost of having Cape Tel IV up and ready to support the launch of an Apollo-Saturn mission.

At first glance, it appears attractive to provide the required VHF telemetry support for the Apollo-Saturn space vehicles during earth parking orbital phases of the mission with the facilities of the CIF instead of Cape Tel IV. However, commitment of the CIF facilities to VHF telemetry support of long duration missions is highly undesirable in view of the role played by the CIF telemetry support facilities in support of the checkout of Apollo-Saturn spacevehicles for subsequent missions.

The MILA MSFN station, which must remain active to support S-band transmissions, currently has a VHF telemetry receive and record capability. The MILA MSFN station, at this time, is equipped with one VHF telemetry tracking antenna, 4 VHF tunable single channel telemetry receivers, 4 VHF tunable dual channel telemetry receivers, 4 diversity combiners, and at least one 14 channel tape recorder. Although each of the dual channel telemetry receivers, only one telemetry link can be received by each dual channel telemetry receiver because the tuner, consisting of common dial tuning, two separate RF and

and mixer stages and one common local oscillator, was designed solely for dual-diversity combining applications. Consequently, the MILA MSFN station has the capability to provide receive support for a total of 8 VHF telemetry links, exclusive of any requirements for spares. In addition, the MILA MSFN station has the capability to route the PCM bit streams received over either the VHF or the S-band PCM telemetry links from the space vehicle to the PCM decommutators located in the station for decommutation.

## 5.1 Coast in Earth Parking Orbit

As stated in Section 4.3, 12 VHF telemetry receivers, exclusive of spares, are required to meet the VHF telemetry support requirements during the earth orbital phases of mission AS-503 representing the worst case of all Saturn-Apollo missions. Examination of Tables 1 through 5 and the support requirements summarized in Sections 2.0 through 4.0 shows that less than 8 VHF telemetry links require support during the earth orbital phases of the all Apollo-Saturn missions with the following exceptions: (a) that 9 VHF telemetry links require support during the earth orbital phases of missions AS-206 and AS-205/8 (although provisions for receiving a VHF FM/FM telemetry link from the S-IVB stage during these missions must be made, this link is not currently scheduled for use and if not used would reduce the VHF telemetry support requirement to 8 links), and (b) 10 VHF telemetry links require support during earth orbital phases of missions AS-501 and AS-502. It should be noted, however, that the Uprated Saturn I Launch Vehicle has a required active lifetime in earth orbit of 4.5 hours and the Saturn V Launch Vehicle has a required active lifetime in earth orbit of 6.5 hours. After these times have been reached in the respective Apollo-Saturn missions or shortly thereafter, support of the telemetry links from the launch vehicle in earth orbit will not be required. Thus at such times, the number of VHF telemetry links requiring support by stations in the MILA/Cape area in the respective Apollo-Saturn missions will be reduced to a maximum of five (5).

Therefore, it is concluded that:

(a) For missions in the AS-200 series and in the AS-500 series prior to AS-504, the MILA MSFN station as now configured can provide the required VHF telemetry support for an Apollo-Saturn spacevehicle after the Saturn launch vehicle becomes inactive so that the Cape Tel IV could be shut down after this time.

(b) For missions in the AS-200 series and in the AS-500 series prior to AS-504, the CIF can provide the required VHF telemetry orbital support for an Apollo-Saturn space vehicle for the short time period that the launch vehicle is active without seriously delaying space vehicle checkout operations of future Apollo-Saturn missions and Cape Tel IV could be shut down after completion of the launch phase, and

(c) For missions AS-205 and 208 (if the FM/FM telemetry systems not presently scheduled for the S-IVB stage is indeed not flown) in the AS-200 series and for missions AS-504 and up in the AS-500 series, the MILA MSFN station as now configured can provide the required VHF telemetry support of an Apollo-Saturn space vehicle after completion of the launch phase and Cape Tel IV could be shut down after launch completion.

## 5.2 Launch Powered Flight

Examination of Table 5 and the support requirements summarized in Sections 2.0 through 4.0 shows that eight (8) VHF telemetry links require support during AS-506 and subsequent Apollo-Saturn missions (assuming that the FM/FM telemetry system not presently scheduled for the S-IVB stage will not be flown, although provisions for this system will be incorporated in the S-IVB stage). All Apollo-Saturn missions prior to AS-506 require support of more than 8 VHF telemetry links during the launch phase (except for mission AS-205 and 208 which require support for 6 VHF telemetry links). However, if the national objective of a manned lunar landing mission prior to 1970 is fulfilled, it may be assumed that missions prior to AS-506 will have been completed before 1970. The possibility of using the VHF telemetry facilities of the MILA MSFN station to replace the Cape Tel IV station to provide the required telemetry support of the Apollo-Saturn space vehicle during the launch phase of AS-506 and subsequent missions is examined in the following paragraphs. Each paragraph will be devoted to the discussion of a different telemetry support requirement which has been abstracted from Section 4.1. It is recognized that the Cape Tel IV station has a much greater VHF telemetry support capability than does the MILA MSFN station.

(a) Reception and recording of all telemetry transmissions from the space vehicle by at least two stations simultaneously is highly desirable during the launch powered flight phase of the mission.

In conjunction with the CIF, which would be the primary VHF telemetry support station, the MILA MSFN station could provide the required support in the MILA/Cape area for reception and recording of all VHF telemetry transmissions from the space vehicle during AS-506 and subsequent missions with existing equipment. No spare VHF channels or equipment would be available at the MILA MSFN station; however, this does not appear to be a problem because the MILA MSFN station only provides a backup to the CIF which in itself will have spare channels, and because the requirement is not "mandatory" but rather "highly desirable." Any difference in coverage provided between the MILA MSFN station and the Cape Tel IV station resulting from differences in look angle from the spacevehicle antennas to the two antenna locations with respect to space vehicle antenna patterns and possibly S-IC stage engine flame effects does not appear to be significant. It should be noted that the S-II stage engine exhaust is expected to have negligible effets on the propagation of electromagnectic waves at VHF or S-band frequencies and that the retrorocket exhaust during S-IC stage separation sequence is expected to black out all telemetry transmissions to either the MILA MSFN station or the Cape Tel IV station. However, comparison of VHF telemetry reception performance of the Cape Tel IV station and the MILA MSFN station during missions early in the AS-500 series would be desirable before a final decision is made. It is known that a station located at Grand Bahama Island (GBI) in conjunction with a station located at Cape Kennedy will provide the required coverage. However, the MSFN station at GBI does not have a VHF telemetry support capability. Any VHF telemetry support of an Apollo-Saturn space vehicle required from a station located at GBI would have to be provided by the AFETR station which currently has the necessary support capability.

(b) Polarization diversity reception of VHF telemetry transmissions from the spacevehicle whenever possible during powered flight phases of the mission.

Polarization diversity reception of all VHF transmissions from the Apollo-Saturn space vehicle during the launch phase of AS-506 and subsequent missions will be provided by the CIF. The MILA MSFN station could provide polarization diversity reception of four VHF telemetry links, presumably the four VHF PCM/FM telemetry

links which require real-time decommutation and data processing for mission control. The reason for the requirement of polarization diversity reception of the VHF telemetry links during launch powered flight is presumably to reduce the possible effects of rocket engine exhaust on the reception of VHF transmissions from the space vehicle. However, as a result of studies performed, The Boeing Company predicts that the S-IC main engine exhaust plume will interfere with RF transmissions to the planned telemetry receiving stations in the MILA/Cape area only during the later portion of the first stage engine burn but will not interfere with RF transmissions to the GBI MSFN station during the later portion of the first stage engine burn for all permissible launch azimuths (72 to 108 degrees) because of the more favorable look angle from the space vehicle antennas to the GBI station. In view of this and since the requirement states, "whenever possible," the existing VHF polarization diversity reception capability of the MILA MSFN station appears to be sufficient.

(c) Reception and recording of telemetry transmissions from the spent stage(s) of the Saturn launch vehicle during ballistic flight following separation is highly desirable.

Since MILA MSFN station is equipped with only one VHF antenna, VHF telemetry reception from the spent stage by the MILA MSFN station will be limited to that provided during the time when the spent stage and the live space vehicle are both within the VHF antenna beamwidth. However, the CIF has available additional VHF telemetry receiving tracking antennas, at least one of which will be used to track and to receive telemetry from the spent stage after separation from the live space vehicle while the primary VHF telemetry receiving tracking antenna of the CIF will be used to track and to receive VHF telemetry from the live space vehicle. Since telemetry from the spent stage after separation is not required for mission control and since there is no requirement for receiving VHF telemetry from the spent stage by two stations, it appears that provision of a second antenna at the MILA MSFN station (the Cape Tel IV station has a second VHF telemetry receiving tracking antenna which is used to track the spent stage) is not necessary to fulfill the telemetry support requirements.

(d) Continuous real-time decommutation of selected telemetry transmissions from the space vehicle and transmission of flight control data to MCC-H during the launch powered phase of the of the mission.

In current planning, the Cape Tel IV station will have the capability of remoting the VHF PCM/FM telemetry links from each stage and the IU and the VHF FM/FM telemetry links from the S-IC and S-II stages to the CIF in real-time during the launch phase of AS-506 and subsequent missions for decommutation and processing prior to insertion into the Data-Core of ALDS for transmission to MCC-H. The MILA MSFN station will have the capability of remoting only one 51.2 kilobit/second PCM bit stream (from the USB system of the CSM) to the CIF in real-time during the launch phase of AS-506 and subsequent missions for decommutation and processing prior to insertion into the Data Core of ALDS for transmission to MCC-H. Consequently, the MILA MSFN station must be provided with the capability of remoting the received VHF telemetry links to the CIF in real-time in order to fulfill the telemetry support requirements during the launch phase of AS-506 and subsequent missions. It is expected that such a modification would be relatively simple and inexpensive.

Therefore, it is concluded that, for missions AS-205 and 208 in the AS-200 series and for AS-506 and subsequent in the AS-500 series, the MILA MSFN station as now configured (with the exception of providing the capability for remoting the received VHF telemetry links to the CIF) in conjunction with the CIF can provide the required VHF telemetry support during the initial portions of the launch phase and that the requirement for the Cape Tel IV station can be eliminated. It should be noted that this conclusion is based on the validity of the assumption that the FM/FM telemetry system not presently scheduled for the S-IVB stage for these missions will indeed not be flown.

A. G. Weygand

2034-AGW-jad

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Attachments
Tables 1 - 5

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TABLE 1

Telemetry Systems to be Carried by the Apollo-Saturn Space Vehicle in Mission AS-204

| Vehicle Location | System Designation | Transmitter Frequency (MHz) | Modulation |
|---|---|---|---|
| S-IB | GF-1 | 240.2 | PAM/FM/FM |
| | GF-2 | 244.3 | PAM/FM/FM |
| | GS-1 | 252.4 | SS/FM |
| | GP-1 | 256.2 | PCM/FM |
| S-IVB | CF-1 | 258.5 | PAM/FM/FM |
| | CF-2 | 246.3 | PAM/FM/FM |
| | CF-3 | 253.8 | PAM/FM/FM |
| | CS-1 | 226.2 | SS/FM |
| | CP-1 | 232.9 | PCM/FM |
| IU | DF-1 | 250.7 | FM/FM |
| | DF-2 | 245.3 | PAM/FM/FM |
| | DS-1 | 259.7 | SS/FM |
| | DP-1 | 255.1 | PCM/FM |
| CSM | | 237.8 | PCM/FM |
| | USB | 2287.5 | PCM/PM/PM or PCM/PM/FM |

TABLE 2

Telemetry Systems to be Carried by the Apollo-Saturn Space Vehicle in Missions AS-205/8 and AS-206

| Vehicle Location | System Designation | Transmitter Frequency (MHz) | Modulation | Mission 206 | Mission 205/8 |
|---|---|---|---|---|---|
| S-IB | GF-1 | 240.2 | FM/FM | x | x |
| | GP-1 | 256.2 | PCM/FM | x | x |
| S-IVB | CF-1* | 253.8 | FM/FM | x | x |
| | CP-1 | 258.5 | PCM/FM | x | x |
| IU | DF-1 | 250.7 | FM/FM | x | x |
| | DP-1 | 255.1 | PCM/FM | x | x |
| CSM | | | | | |
| | USB | 2272.5 | PCM/PM/FM | | x |
| | USB | 2287.5 | PCM/PM/PM | | x |
| LM | | 230.9 | FM/FM | x | x |
| | | 237.8 | PCM/FM | x | x |
| | | 241.5 | PAM/FM/FM | x | x |
| | | 247.3 | PAM/FM/FM | x | x |
| | | 257.3 | PAM/FM/FM | x | x |
| | USB | 2282.5 | PCM/PM/PM or PCM/PM/FM | x | x |

*Not presently scheduled, but provisions to carry this system are incorporated.

TABLE 3

Telemetry Systems to be Carried by the Apollo-Saturn Space Vehicle in Missions AS-501 through AS-503

| Vehicle Location | System Designation | Transmitter Frequency (MHz) | Modulation | Mission 501 | 502 | 503 |
|---|---|---|---|---|---|---|
| S-IC | AF-1 | 240.2 | PAM/FM/FM | x | x | x |
| | AF-2 | 252.4 | PAM/FM/FM | x | x | x |
| | AF-3 | 231.9 | PAM/FM/FM | x | x | x |
| | AS-1 | 235.0 | SS/FM | x | x | x |
| | AS-2 | 256.2 | SS/FM | x | x | x |
| | AP-1 | 244.3 | PCM/FM | x | x | x |
| S-II | BF-1 | 241.5 | PAM/FM/FM | x | x | x |
| | BF-2 | 234.0 | PAM/FM/FM | x | x | x |
| | BF-3 | 229.9 | PAM/FM/FM | x | x | x |
| | BS-1 | 227.2 | SS/FM | x | x | x |
| | BS-2 | 236.2 | SS/FM | x | x | x |
| | BP-1 | 248.6 | PCM/FM | x | x | x |
| S-IVB | CF-1 | 258.5 | PAM/FM/FM | x | x | x |
| | CF-2 | 246.3 | PAM/FM/FM | x | x | x |
| | CF-3 | 253.8 | PAM/FM/FM | x | x | x |
| | CS-1 | 226.2 | SS/FM | x | x | x |
| | CP-1 | 232.9 | PCM/FM | x | x | x |
| IU | DF-1 | 250.7 | FM/FM | x | x | x |
| | DF-2 | 245.3 | PAM/FM/FM | x | x | x |
| | DS-1 | 259.7 | SS/FM | x | x | x |
| | DP-1 | 255.1 | PCM/FM | x | x | x |
| | DP-1A | 2277.5 | PCM/FM | x | x | x |
| | CCS | 2282.5 | PCM/PM/PM | x | x | x |
| CSM | | 237.8 | PCM/FM | x | x | |
| | | 2272.5 | PCM/PM/FM | | | x |
| | | 2287.5 | PCM/PM/PM | x | x | x |
| | USB | 2287.5 | PCM/PM/FM | x | x | |

TABLE 3 (Cont.)

Telemetry Systems to be Carried by the Apollo-Saturn Space Vehicle in Missions AS-501 through AS-503

| Vehicle Location | System Designation | Transmitter Frequency (MHz) | Modulation | Mission 501 | 502 | 503 |
|---|---|---|---|---|---|---|
| LTA or LM | | 228.2 | PAM/FM/FM | | | x* |
| | | 230.9 | FM/FM | x | x | x* |
| | | 237.8 | PCM/FM | | | x* |
| | | 247.3 | PAM/FM/FM | x | x | x* |
| | | 257.3 | PAM/FM/FM | | | x* |
| | USB | 2282.5 | PCM/PM/PM or PCM/PM/FM | | | x |

*Presently scheduled, but this system may be eliminated.

TABLE 4

Telemetry Systems to be Carried by the Apollo-Saturn Space Vehicle in Missions AS-504 and AS-505

| Vehicle Location | System Designation | Transmitter Frequency (MHz) | Modulation |
|---|---|---|---|
| S-IC | AF-1 | 240.2 | PAM/FM/FM |
| | AF-2* | 252.4 | PAM/FM/FM |
| | AF-3* | 231.9 | PAM/FM/FM |
| | AS-1* | 235.0 | SS/FM |
| | AS-2* | 256.2 | SS/FM |
| | AP-1 | 244.3 | PCM/FM |
| S-II | BF-1 | 241.5 | PAM/FM/FM |
| | BF-2 | 234.0 | PAM/FM/FM |
| | BF-3 | 229.9 | PAM/FM/FM |
| | BS-1 | 227.2 | SS/FM |
| | BS-2 | 236.2 | SS/FM |
| | BP-1 | 248.6 | PCM/FM |
| S-IVB | CF-1** | 253.8 | FM/FM |
| | CP-1 | 258.5 | PCM/FM |
| IU | DF-1 | 250.7 | FM/FM |
| | DP-1 | 245.3 | PCM/FM |
| | DP-1A *** | 2277.5 | PCM/FM |
| | CCS *** | 2282.5 | PCM/PM/PM |
| CSM | USB | 2272.5 | PCM/PM/FM |
| | USB | 2287.5 | PCM/PM/PM |
| LM | USB | 2282.5 | PCM/PM/PM or PCM/PM/FM |

*This telemetry system may be eliminated on missions AS-504 and AS-505.

**This telemetry system is not currently scheduled, but provisions for this system will be incorporated.

***This telemetry system is presently scheduled, but one of these systems may be eliminated.

TABLE 5

Telemetry Systems to be Carried by the Apollo-Saturn Space Vehicle in Missions AS-506 and Up

| Vehicle Location | System Designation | Transmitter Frequency (MHz) | Modulation |
|---|---|---|---|
| S-IC | AF-1 | 256.2 | FM/FM |
| | AP-1 | 244.3 | PCM/FM |
| S-II | BF-1 | 241.5 | FM/FM |
| | BF-2 | 234.0 | FM/FM |
| | BP-1 | 248.6 | PCM/FM |
| S-IVB | CF-1* | 253.8 | FM/FM |
| | CP-1 | 258.5 | PCM/FM |
| IU | DF-1 | 250.7 | FM/FM |
| | DP-1 | 245.3 | PCM/FM |
| | DP-1A | 2277.5 | PCM/FM |
| | CCS | 2282.5 | PCM/PM/PM |
| CSM | USB | 2272.5 | PCM/PM/FM |
| | USB | 2287.5 | PCM/PM/PM |
| LM | USB | 2282.5 | PCM/PM/PM or PCM/PM/FM |

*This telemetry system is not currently planned, but provisions for this system will be incorporated.